ARM

CLIMATE RESEARCH FACILITY

RECOVERY ACT ENHANCEMENTS

Overview

Sponsored by the U.S. Department of Energy Office of Science, the Atmospheric Radiation Measurement (ARM) Climate Research Facility maintains heavily instrumented field sites in Oklahoma, Alaska, and the tropics. Operating since the mid-1990s, these fixed sites obtain continuous measurements of a broad range of atmospheric conditions, such as cloud profiles, aerosols, precipitation, and solar and terrestrial radiation.

Mirroring these permanent sites, two ARM Mobile Facilities provide portable instrumented platforms for obtaining measurements in data-poor regions for up to 12 months at a time. Supplementing these ground-based measurement capabilities, similar airborne measurements are obtained through the ARM Aerial Facility. These data allow researchers around the world to study and improve the way atmospheric processes are represented in climate models.

American Recovery and Reinvestment Act of 2009

Through the Recovery Act, the ARM Facility received $60 million for new and upgraded instrumentation, equipment, and infrastructure to improve the atmospheric data sets used in regional and global climate models. With these funds, the ARM Facility procured or built 132 new instrument systems, including:

- scanning cloud and precipitation radars
- advanced light detection and ranging (lidar) technologies
- energy exchange measurement systems
- in situ aerosol sampling and aerial instrumentation.

In addition to these new measurement capabilities, several long-standing instruments were upgraded or replaced. The ARM Facility now provides unmatched measurement capabilities that permit the world's most detailed documentation of cloud characteristics and their evolution ever obtained. These details will help scientists reduce the two largest uncertainties in climate models: the roles of clouds and aerosols in climate change.

For more information about the Recovery Act investments throughout the ARM Facility, including a comprehensive listing of purchased and enhanced instruments, visit the ARM Recovery Act web page at ***http://www.arm.gov/about/recovery-act***.

New Measurements for Climate Research. *Recovery Act enhancements throughout the ARM Facility were carefully selected based upon the particular needs of each site, including upgrades to complete and modernize the existing instrument collection and adding new measurement capabilities. The distribution of the new and upgraded instrument systems follows.*

10 for the North Slope of Alaska

21 for the Southern Great Plains

31 for the Tropical Western Pacific

26 for the ARM Mobile Facilities

18 for the ARM Aerial Facility

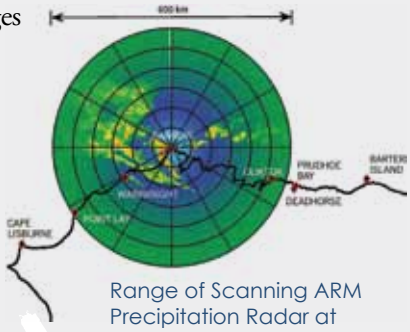
19 for a new Mobile Aerosol Observing System

7 spares for use as needed throughout the ARM Facility

Scientific Impact

Recovery Act enhancements throughout the ARM Facility reflect the need for detailed measurements of key atmospheric processes—particularly those involving clouds and aerosols. These measurements provide the essential building blocks for climate models, which are currently the only tools available to anticipate the climate of future decades and centuries.

North Slope of Alaska



Range of Scanning ARM Precipitation Radar at the North Slope of Alaska.

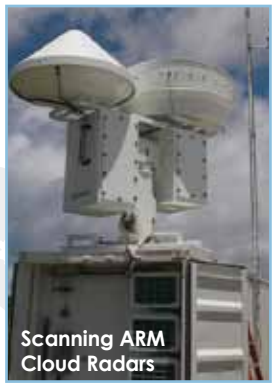
Dramatic changes in the Arctic—which appear to be driven primarily by increasing clouds and precipitable water vapor—are occurring at rates greater than predicted. Routine observations from three new scanning radars greatly expanded the NSA site's ability to detect and quantify the structure, spatial distribution, and evolution of Arctic clouds and precipitation. Other new instruments close a gap in observations of surface boundary conditions and allow for characterization of the physical properties of clouds over Barrow, particularly those associated with mixed-phase clouds composed of both liquid and ice.

Southern Great Plains

Due to its relatively homogeneous geography and continental locale, the SGP site serves as a good testbed for single-column models and cloud-resolving models. Now, the simultaneous operation of multiple radar and lidar systems within the SGP domain provides an unparalleled capability for "interrogating" the growth and decay of individual clouds and their interactions with the larger associated weather systems.

Tropical Western Pacific

Detailed measurements from the tropical warm pool regime—Earth's "heat engine"—are essential to fully understand and model the planet's atmospheric circulation and climate. New scanning cloud radars at the TWP sites allow far better characterization of the complex convective cloud fields than is possible with traditional vertical-pointing cloud radars. Meanwhile, the new scanning precipitation radar provides an important constraint for model simulations of the equatorial tropical climate regime.



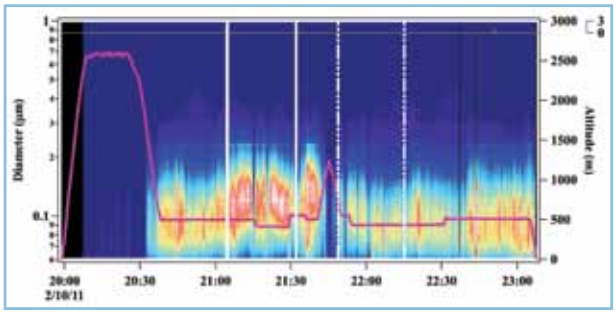
Scanning ARM Cloud Radars

ARM Mobile Facilities

The two AMF provide the means to apply the comprehensive array of ARM measurements to diverse climatic regimes. New instruments from the Recovery Act will allow scientists to better explore cloud and aerosol properties in under-sampled regions around the world.

ARM Aerial Facility

Recovery Act funding more than tripled the number of instruments available in the AAF—ARM's "site in the sky." State-of-the-art instrumentation measures in situ atmospheric state parameters, cloud and aerosol properties—including particle-size detection from 15 nanometers to 2 centimeters—and concentrations of numerous climate-relevant gases. New cloud probe designs provide unbiased measurements of the size distribution of ice particles, which equates to more accurate model input. In addition, faster electronics and data processing software have greatly increased the sensitivity of the probes to detect very low concentrations of both aerosols and cloud particles.



Aerosol size and concentration from the Ultra High Sensitivity Aerosol Spectrometer.

Cloud Properties and Life Cycle

Millimeter wavelength radars are used to obtain measurements of the horizontal and vertical distributions of clouds, as well as the sizes and shape of the water and ice that compose the clouds.

Scanning Cloud and Precipitation Radars

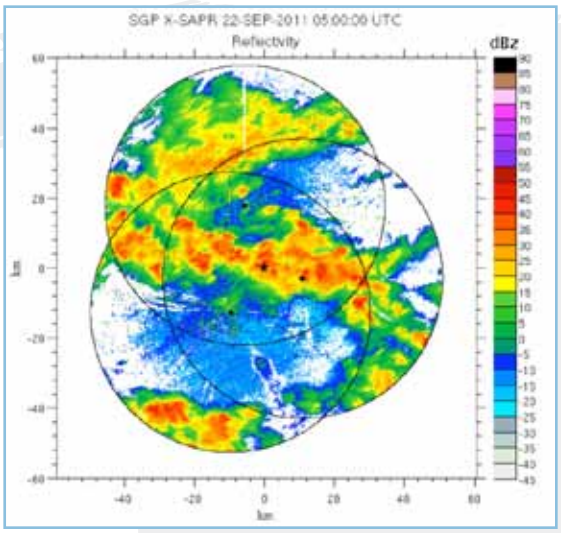
An unprecedented assortment of 19 new scanning radars provides a unique capability for high-resolution delineation of cloud evolution, morphology, and characteristics. All these radars are equipped with dual-polarization technology which, combined with multiple frequencies, provides improved retrievals of cloud properties, including better discrimination of liquid from ice.

- 35/94-gigahertz (Ka/W-band) scanning ARM cloud radars at SGP, NSA, and with AMF1
- 35/10-gigahertz (Ka/X-band) scanning ARM cloud radars at TWP sites (2) and with AMF2
- 10-gigahertz (X-band) and 5-gigahertz scanning ARM precipitation radar at SGP (3) and NSA
- 5-gigahertz (C-band) scanning ARM precipitation radar at SGP and TWP-Manus

Cloud Probes for In Situ Measurements

In situ data is critical for validating measurements obtained from both ground-based and satellite remote sensing instruments. Six new cloud probes, all with the newly designed tips and faster electronics, reduce the effects of particle shattering to provide more accurate measurements for model development and validation studies.

- Fast forward scattering spectrometer
- 2-dimensional imaging probe
- High-volume precipitation spectrometer
- Cloud spectrometer and impactor
- Fast cloud droplet probe
- Liquid ice water sensor



Overlapping precipitation radars surround the cloud radars (star in center) at the SGP site

3-Channel Microwave Radiometer

A new 3-channel microwave radiometer at all the ARM sites provides improved sensitivity to liquid water when the liquid water path is less than 100 grams per square meter, offers improvements in the spatial and temporal resolution of the measurements, and matches as closely as possible the field of view for all channels.

The high-volume precipitation spectrometer (front) measures the number and size of precipitation particles, including snowflakes, from 150 microns to 1.92 centimeters in size. This is the only aircraft research instrument of its kind that provides complete digital images of precipitation particles up to nearly 2 centimeters in size.




Enhanced Aerosol and Atmospheric Chemistry Observations

A new array of aerosol and chemistry instruments will allow scientists to analyze the life cycle of aerosols, characterize aerosols through the vertical column, and study interactions between aerosols and clouds.

In Situ Aerosol Observing Systems

These complex systems provide a wide array of aerosol measurements: absorption, concentration, and scattering; backscattered radiation; cloud-condensation nuclei; hygroscopic growth; inorganic chemical composition; and particle number concentration and size distribution. These measurements are acquired by a comprehensive suite of instruments: two nephelometers, a light absorption photometer, a condensation nuclei counter, and an ozone monitor.

A modernized Aerosol Observing System is now deployed at the SGP site, while brand-new systems are located at the TWP Darwin site and with the AMF2. Each AOS is collocated with a complementary lidar system to obtain vertical profiles of aerosol extinction.

In addition, the Recovery Act funded the development of a new mobile AOS that provides additional capabilities for determining aerosol composition and trace gases, which are the precursors to aerosol formation. This new system is composed of separate aerosol and chemistry units in dedicated 20-foot containers that can be deployed together or separately. Many of these instruments are also available in scaled versions to support airborne research through the AAF.

Active and Passive Remote Sensing

Similar in operation to radar, various lidar systems are optimized for different types of measurements. Two new lidar systems are now measuring atmospheric trace gas concentration and cloud and aerosol optical properties.

- **High Spectral Resolution Lidar**. Optical filters in the HSRL can distinguish between photons scattered from air molecules and those scattered by aerosol or cloud particles. This enables the HSRL to measure aerosol optical properties more directly than any other lidar system. This lidar is operating at the NSA and with the AMF2.
- **Raman Lidar**. Developed for the ARM Facility as the first turn-key operational Raman lidar in the world, this system has been in continuous operation at the SGP site since 1996. Signals from its various channels are processed to generate a number of aerosol-related measurements, including scattering ratio, backscatter, extinction, and absorption. The SGP system is now fully upgraded, and a brand-new system is operating at the TWP Darwin site.

In addition to lidar, two new Solar Array Spectrometer systems—a zenith (vertical-pointing) system and a hemispheric (180-degree field-of-view) system—operate in tandem to provide information about aerosol optical properties and composition.

Atmospheric State Observations and Surface Fluxes

To understand the life cycle of clouds and aerosols, scientists need measurements of the atmospheric state, such as water vapor, temperature, and air motion (including vertical velocity). Together with measurements of surface heat fluxes, these parameters can be used to constrain model simulations or provide auxiliary information for studying the formation and evolution of clouds and aerosols.

Water Vapor and Air Motion

Observations of vertical velocities, particularly in clear air, are challenging to obtain. New lidar systems will primarily operate in vertically pointing mode to concentrate on measurements of vertical air velocity.

- **Doppler Lidar**. Full upper-hemispheric scanning capabilities of the Doppler lidar enable 3-dimensional mapping of turbulence structure and measurements of horizontal wind profiles in the lowest 3–4 kilometers of the atmosphere. These new lidars are located at the SGP site, the TWP Darwin site, and with AMF1.
- **Raman Lidar**. In addition to aerosol measurements, the Raman lidar provides high temporal resolution profiles of water vapor. This unique capability at the TWP Darwin site will be very useful for obtaining a highly detailed view of moistening and drying processes in the tropics.

In addition, new 1290-megahertz and upgraded 915-megahertz radar wind profilers are obtaining vertical profiles of wind speed and direction. Similar measurements at the 1000-to-4000-hertz range are provided by a new sonic detection and ranging system.

Surface Fluxes

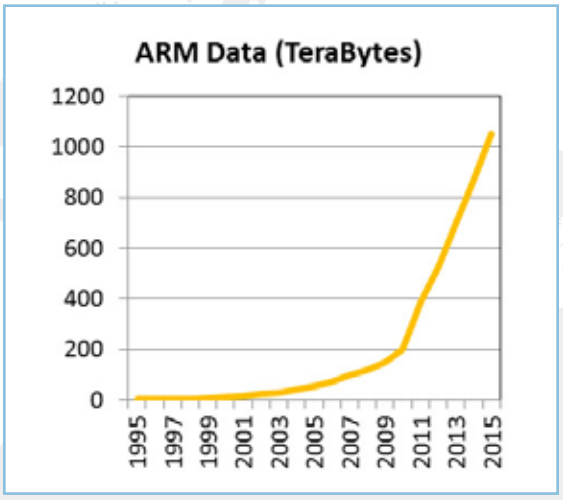
Based on how they interact with cloud and atmospheric dynamics, land-use changes can have an effect on Earth's energy balance. Scientists use measurements of canopy temperature, vapor pressure deficit, and soil moisture to analyze the degree of energy exchange and predict the onset of cloud formation. New surface energy balance systems in the tropics and at the North Slope will significantly expand the regimes for which ARM provides surface flux observations.

New Data for Scientific Discovery

Raw data collected from ARM's fixed and mobile sites are processed at the ARM Data Management Facility, then made available through the ARM Data Archive, where they are stored and freely available to the science community. The new instruments, particularly the radars, represent a 50 percent increase in data volume, requiring significant enhancements to the data infrastructure at the sites as well as the central processing and storage centers.

The upgraded equipment and systems process data 3 to 7 times faster than the old systems and provide 10 to 20 times more capacity to accommodate current and future storage and processing demands. New processes have also been developed to move the new very large data sets from remote sites to the DMF.

Airborne Data System. Funding from the Recovery Act allowed the AAF to develop an onboard local area network system capable of data transfers up to 125 megabytes per second. This onboard data system allows scientists to remain safely seated while monitoring data gathered during flights. In addition, scientists on the ground can monitor real-time data during flight operations and coordinate with onboard scientists using instant messaging.



As Good as New

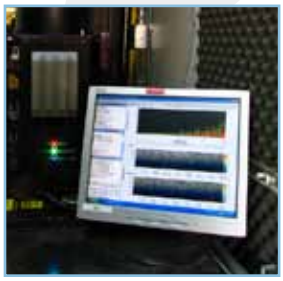
Though not brand-new measurement capabilities, various core ARM instruments were upgraded or replaced through the Recovery Act, including:

- *Atmospheric emitted radiance interferometers*
- *Ceilometers*
- *Micropulse lidars*
- *Microwave radiometers*
- *35-gigahertz zenith-pointing radars.*

Advanced Data Products

Taking full advantage of the new measurement capabilities will require the development of advanced data products based on current analysis techniques. It will also require research investments to explore ways to extract the maximum information from this unique array of instruments. Goals for these measurements include:

- Profiles of cloud properties, including liquid and ice water content and droplet size
- 3-dimensional cloud distributions
- Estimates of spatially quantified precipitation
- Profiles of aerosol properties, including scattering, absorption, particle size, and composition
- Vertical velocity in clear air and clouds.



Proposals for conducting field campaigns at ARM sites are welcome from all members of the scientific community.

Each year, a call for proposals to use the ARM Facility is issued via advertisements in scientific news publications and on the ARM website. The proposal cycle generally begins around November.

Full proposals are reviewed each August at the annual meeting of the ARM Science Board. While considering their recommendations, acceptance of the proposal remains at the discretion of DOE program management.

Although ARM does not provide direct funding for scientific research, it may provide limited funding to assist with logistics, development of datastreams and archiving, and other infrastructure activities associated with using the ARM Facility. Research funds for successful proposals will be provided by the Atmospheric System Research program.

http://www.arm.gov/campaigns/propose

http://www.arm.gov/about/recovery-act

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